

Introduction: Water in the interior of terrestrial planets can be dissolved in fluids or melts and hydrous phases, but can also be locked as protons attached to structural oxygen in lattice defects in ‘nominally’ anhydrous minerals (NAM) like olivine, pyroxene, or feldspar [1-3]. Although these minerals contain only tens to hundreds of ppm H₂O, this “water” can amount to at least one ocean in mass when added at planetary scales because of the modal dominance of NAM in the mantle and crust [4]. Moreover these trace amounts of water can have drastic effects on melting temperature, rheology, electrical and heat conductivity, and seismic wave attenuation [5]. There is presently a debate on how much water is present in the martian mantle. Secondary ionization mass spectrometry (SIMS) studies of NAM [6], amphiboles and glass in melt inclusions [7-10], and apatites [11, 12] from Martian meteorites report finding as much water as in the same phases from Earth’s igneous rocks. Most martian hydrous minerals, however, generally have the relevant sites filled with Cl and F instead of H [13, 14], and experiments using Cl [15] in parent melts can reproduce Martian basalt compositions as well as those with water [16]. We are in the process of analyzing Martian meteorite minerals by Fourier transform infrared spectrometry (FTIR) in order to constrain the role of water in this planet’s formation and magmatic evolution.

Results and discussion: Analysis of two pyroxene grains from nakhlite MIL 03346 yield a minimum of 1.6 ppm H₂O in each grain while one pyroxene grain from nakhlite NWA 998 contains about 4 ppm H₂O (Figure). These water contents are at least 100 times lower than those found in terrestrial pyroxenes [3]. Nakhlites are thought to represent the cumulate part of thick lava flows [17]. The augitic pyroxene is their main phase and crystallized first from the parental magma [18, 19]. However, melts may have circulated through the cumulate pile and reacted with it. In that respect MIL 03346 represents the least re-equilibrated of the nakhlites while NWA 998 is the most compositionally transformed by this process [18, 19]. The water contents of a melt in equilibrium with the pyroxenes can be calculated using the partition coefficient equation of [20]. A melt in equilibrium with MIL 03346 pyroxene would contain 200 ppm H₂O. If this value represents the water content of the parent melt, then the martian mantle produces relatively dry magmas compared to that of Earth (for example melt inclusions in olivines from primitive MORBs contain 1200 ppm H₂O [21]). The higher water content of NWA 998 pyroxene may reflect re-equilibration for water with percolating more evolved melts containing at least 400 ppm H₂O. This scenario would be consistent with the water content of 619-1100

ppm that has been measured in NWA 998 apatite [11], one of the last phase to crystallize. A melt in equilibrium with that apatite would contain a minimum of 2800 ppm water using a partition coefficient apatite-melt of 0.25 [22]. Alternatively, and although nakhlites are the least shocked of all Martian meteorites [17], water in these pyroxenes may have been in part lost during impact, although experimental studies are necessary to validate this speculation.

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Figure: Transmission polarized FTIR spectra of nakhlite pyroxenes in the O-H vibration region. The fact that the OH bands (in blue) change in position and height with rotation of the infrared polarizer (2 perpendicular directions shown for each pyroxene grain (xl)) demonstrates that they are caused by H defects intrinsic to the pyroxene. 3625, 3520 & 3450 are typical clinopyroxene OH bands.

